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REPORT OF INVESTIGATIONS 180

MAZOSTACHYS—A NEW CALAMITE FRUCTIFICATION

BY

ROBERT M. KOSANKE

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS

1955

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MAZOSTACHYS—A NEW CALAMITE FRUCTIFICATION

BY

ROBERT M. KOSANKE

ABSTRACT

The specimen described is preserved in an ironstone concretion collected from spoil piles of the No. 2 coal bed of Pennsylvanian age in Will County, Ill. It is a calamite shoot bearing fifteen cones. Each cone axis, with nodes and internodes, bears appendages of two types. A whorl of twelve bracts occurs on each node and high on each internode are six whorled sporangiophores. Whorls of sporangiophores and bracts alternate along the vertical extent of the cone axis. Two sporangia are attached to each sporangiophore in a pendulant manner. The striking features of this type of calamite fructification are: (1) the position of attachment of the sporangiophore, and (2) the presence of two sporangia per sporangiophore, a new feature of calamite fructifications. The second feature demonstrates that the phylogeny has progressed with reduction in number of sporangia per sporangiophore from four in *Asterocalamites Pothocites, Protocalamostachys, Calamostachys, Palaeostachya,* and *Cingularia typica,* to two in this specimen (described as *Mazostachys*), to only one in *Metacalamostachys. Mazostachys* is homosporous. The foliage of *Annularia sphenophylloides* occurs in the ironstone concretion in association with *Mazostachys* but not in organic connection with the fertile shoot.

INTRODUCTION

The following report is a contribution to fundamental studies of fossil plants of Pennsylvanian age of Illinois. It is a continuation of the Survey's efforts to explore past plant life seeking knowledge of coal-forming plants of potential value in the correlation of coal beds and in related studies in the field of coal petrography. Studies of fossil cones are also useful to paleobotanists in associating isolated spores in coal with their parent plants.

This report describes a new type of calamite fructification and gives a re-evaluation of previous ideas on the phylogeny of these fructifications in light of new evidence. The specimen, with preserved cellular structure, was found in an ironstone concretion on the spoil piles of the stripping operations of the Northern Illinois Coal Corp., near the Mazon Creek area, Will County, Ill.

Ironstone concretions with preserved plant remains occur in the Francis Creek shale immediately above the No. 2 coal bed in the area. It is assumed that the ironstone concretion bearing the specimen of *Mazostachys* was removed from the shale during stripping operations.

The Francis Creek shale lies in the lower part of the Carbondale group of Pennsylvanian age in Illinois. According to Moore et al. (1944), an equivalent stratigraphic position in the mid-continent region would be in the upper Cherokee group of the Des Moines series and in the Allegheny series of the Appalachian region of eastern United States. For additional information about the Francis Creek shale, see Cady (1919), Savage (1927), Wanless (1929), and Willman and Payne (1942).

The external appearance of the concretion containing the specimen of *Mazostachys* is typical of others found in the area, but the mode of preservation is not entirely of the compression type. The main axis and branches of the specimen are principally carbonaceous material, but each cone is encased in, or surrounded by, calcium carbonate. Therefore, preservation is somewhat similar to a coal ball in which histological details can be observed. Peels and thin sections were used in studying the preserved cellular structure of the fructifications. Individual sporangia from several

cones were dissected and macerated so that the spores could be studied individually in the isolated state. Specimens with preserved cellular structure from the Mazon Creek area are rare, but the author has a specimen of *Calamostachys* which is not as well preserved as the specimen described. Darrah (1936) described *Macrostachya thompsonii* in an ironstone concretion from the Mazon Creek area that is preserved in a similar manner.

Ironstone concretions containing plant compressions occur at a number of stratigraphic levels and in various areas of the United States. I have observed these concretions from a shale overlying the Pomeroy coal bed in Ohio, above the Minshall coal bed in Warren County, Ind., and above the Murphysboro coal bed in southwestern Illinois. Condit and Miller (1951) reported plant-bearing ironstone concretions from Iowa.

Acknowledgments

It is a pleasure to acknowledge the assistance of Dr. Wilson N. Stewart, under whose supervision this report was submitted in 1952 to the Graduate College, University of Illinois, as part one of a doctoral thesis in botany. Dr. Theodore Just, Chicago Natural History Museum, assisted in the selection of the new names proposed. Dr. James R. Kamp and Mr. and Mrs. John M. McLuckie, Coal City, Ill., assisted in obtaining the described specimen.

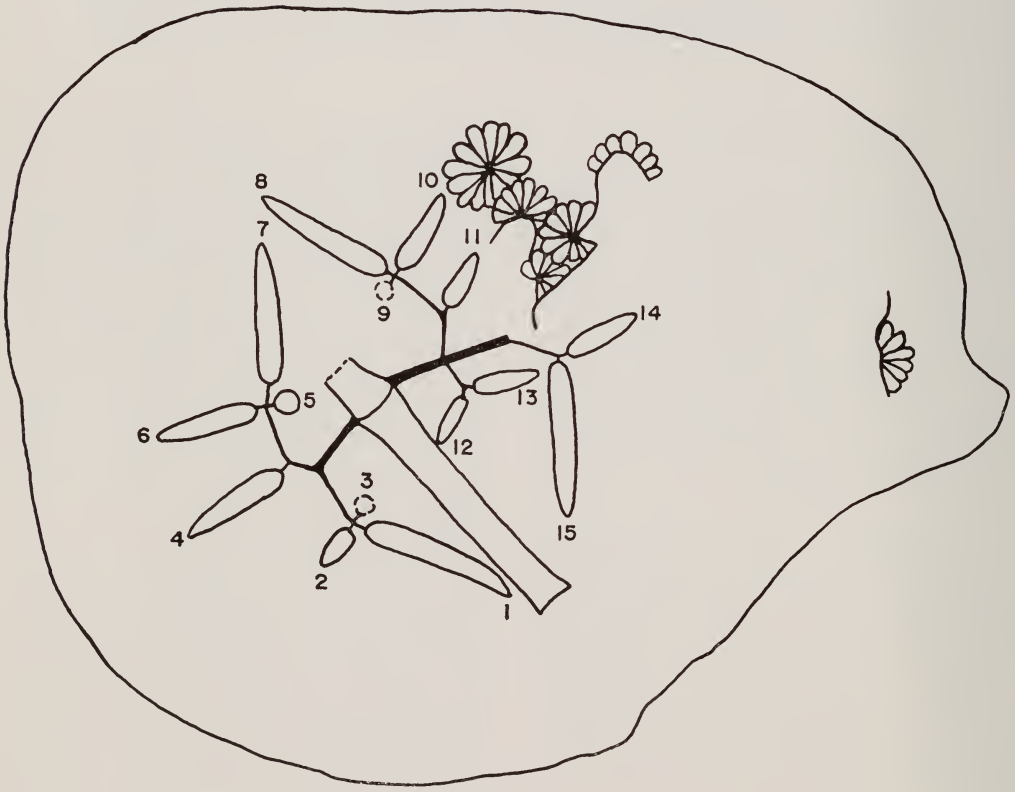

Fig. 1.—A diagrammatic drawing of the holytype specimen of *Mazostachys pendulata* gen. et sp. nov. (B-1304A). The cones were assigned numbers for ease of discussion in text. Cones 3 and 9 did not occur on this half of the specimen, so their position is shown by dashed lines. About 7/8 natural size.

MAZOSTACHYS PENDULATA GEN. ET SP. NOV.

GENERAL DESCRIPTION

The specimen is in the Illinois State Geological Survey, paleobotanical collection, number B-1304. It was split in half and, accordingly, will be referred to as B-1304A and B-1304B (figs. 1 and 2; pl. 1, fig. 1; and pl. 4, fig. 1). It is a fertile calamite shoot with 15 attached cones. Foliage is not attached, but six whorls of leaves identified as *Annularia sphenophylloides* are preserved as a very thin carbonaceous film in the same plane as the specimen.

The shoot axis has two nodes and one complete internode. There is also a small portion of another internode. The complete internode is 4.2 cm. long and slightly less than 1 cm. wide. Two branches depart from the shoot axis opposite each other; thus the mode of branching places this specimen in the subgenus *Eucalamites*, typified by *Calamites carinatus* as illustrated by Hirmer (1927, figs. 537 to 543). Each branch redivides (figs. 1 and 2), one bearing seven cones and the other eight. The divisions of the two branches are somewhat irregular and not entirely typical of *Calamites carinatus*. The internode of each branch is 1 cm. long and less than 2 mm. wide. The branch that gives rise to cones 1 through 7 (figs. 1 and 2) bifurcates; one dichotomy gives rise to cones 1 through 3 and the other dichotomy bears cones 4 through 7. The branch giving rise to cones 8 through 15 divides in true eucalamite style at the first node. Cones 12 and 13 are formed in the same manner. The first node of the other division gives rise to cone 11 and a sterile node leading to the culmination of cones 8 through 10 (as in the formation of cones 4 through 7). The second node of the branch bearing cones 8 through

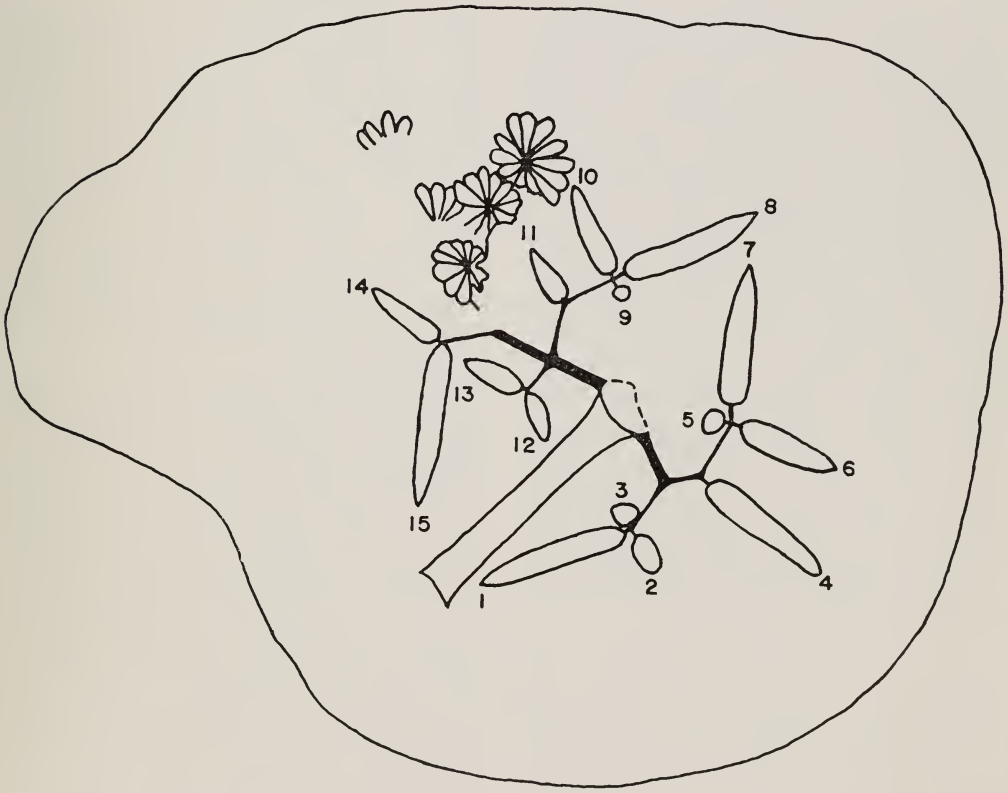

FIG. 2.—A diagrammatic drawing of the holotype specimen of *Mazostachys pendulata* gen. et sp. nov. (B-1304B). All fifteen cones occur on this half of the specimen. About 7/8 natural size.

15 appears to bifurcate, with one of the resulting branches bearing cones 14 and 15 and the other perhaps bearing foliage. There is no organic connection between the cone-bearing and leaf-bearing shoots, but their proximity suggests that they may belong to the same plant.

Each cone is attached to a short peduncle usually less than 2 mm. in length; the peduncle for cone 7 is somewhat longer.

The cones vary in length, depending upon the number of whorls per cone. Cone 1 has nine whorls; cones 8 and 15, eight; cones 4 and 7, seven; cone 6, six; cones 10 and 14, five; cones 11, 12, and 13, three; and cones 2, 3, and 9, one. The largest cone is number 1, which is 2.6 cm. long and just under 4 mm. wide.

SHOOT AXIS

The shoot axis is preserved as a true compression. Three peels of B-1304A contained carbonaceous matter, whereas only the first peel of B-1304B contained any appreciable carbonaceous matter. Because of degradation and poor structural preservation, superficial ribbing and furrowing is apparent only from the external surface of the shoot. Examination of peels shows only a few scattered tracheids with scalariform and multiseriate scalariform pitting, the latter similar to that described by Delevoryas and Morgan (1952). Similar pitting was termed scalariform or multiseriate pitting by Høeg (1942). Patches of parenchyma cells were observed, but these could not be correlated with any specific tissues of the shoot axis. The branches arising from the shoot axis are also poorly preserved, and only a few tracheids with scalariform pitting were observed. Parenchyma cells are present, and their position suggests a central pith.

PEDUNCLES

The peduncles attached to the cones are exceedingly thin, delicate structures, and their preservation is very poor. Only one or two peels in which peduncles were included contained structural details. These consisted of patches of preserved parenchyma and a few tracheids with scalariform and multiseriate scalariform pitting. There is no indication of a pith cavity.

CONE AXIS

The preservation of the cone axis is usually good except for the phloem and cortex. Tracing the vascularization in the longitudinal section is difficult, owing to its slender nature and to the fact that these axes are preserved with minor curvatures or twists. Plates 2 and 3 show the axis of cone 14 in transverse section from the base of the sporangia of the second whorl from the proximal end of the cone to the base of the sporangia of the next higher whorl (pl. 1, fig. 2). Thirty-eight peels were made between these two points, a distance of approximately 1900 microns.

It is apparent from an examination of plates 2 and 3 that no internodal pith cavity is present in the transverse sections of the cone axis. The absence of a pith cavity in longitudinal section may be seen in figure 3, plate 1, and figure 1, plate 6. In this respect, *Mazostachys pendulata* sp. nov. is similar to *Calamostachys binneyana*.

The pith is composed of parenchyma cells which are largest in diameter at the center of the cone axis. At the middle of the internodes, these cells are about seven times longer than their maximum width. Between the vascular bundles they are about one-half this size.

Carinal canals are located between the extensions of the pith of the internodal region, at the level of departure of the sporangiophore traces (pl. 5, fig. 1). Six canals are still evident at the level of the bract traces, but they fuse or pair a short distance above this level, where they lie adjacent to three regions of secondary wood similar to *Calamostachys binneyana* as illustrated by Williamson and Scott (1894). In a transverse section of cone 14 (B-1304A), peel 25, four carinal canals are paired close together, whereas two are still somewhat separated. All ultimately pair and fuse at a slightly higher level on the axis, so a somewhat triangular stele re-

sults at a point just above the middle of the nodal region. The pairing of carinal canals is believed to be the result of rearrangement of cells in the nodal region. An attempt was made to determine whether or not there is an alternation of vascular bundles between successive nodes, a possibility strongly suggested by the pairing of the carinal canals. Peels 1 through 38 of cone 14 were examined and no evidence was found for an alternation of the bundles, although there is a shift in the position of the carinal canals. This shift could be due in part to preservational factors.

The protoxylem of the cone axis is largely disintegrated, leaving the carinal canals. The remains of annular protoxylem elements line the canal walls. Plate 4, figure 3, shows the protoxylem remains in the canal. Portions of three tracheids lie side by side, filling the canal at a point near the top of the figure. It is believed that the protoxylem mass, prior to the formation of the canals, was composed of three, perhaps four, vertical rows of tracheids. At the periphery of the protoxylem is the metaxylem; its tracheids have scalariform pitting (pl. 4, fig. 3). The remains of an annular protoxylem element may be seen in plate 5, figure 1.

No evidence was found that the secondary wood forms a complete ring in the nodal region. In all sections prepared, portions of the pith extend between the vascular bundles to the periphery of the preserved portion of the cone axis, although in several sections the peripheral width of the parenchyma was only one or two cells. The phloem, cortex, and epidermis are not preserved, so it is possible that a portion of the secondary wood is also missing. The vascular tissue in the enlarged nodal region displays scalariform (pl. 4, fig. 6), multiseriate scalariform (pl. 6, fig. 4), and reticulate pitting of the metaxylem and secondary wood. Node enlargement in the cone axis results from formation of secondary wood and departure of vascular traces, as in *Palaeostachya vera* and *Calamostachys binneyana*.

The cone axis of *Mazostachys pendulata* sp. nov. is a dictyostele consisting of separate vascular bundles which form a network. The primary xylem develops centrifugally and is endarch in arrangement. Only a few annular thickenings of the protoxylem remain in the carinal canals. Abundant metaxylem lies to the outside of the canals of the internodal region. Secondary wood is developed at the nodes and beyond the metaxylem. Tissues from the cambium to the epidermis are not preserved. Measurements of a number of cones in transverse and longitudinal section show that the maximum preserved nodal diameter is 750 microns at the base of the cone. In cone 1 this nodal diameter decreases to 450 microns at the cone apex. From base to apex of the cones, the internodal diameter decreases from about 475 microns to about 325 microns.

BRACTS

There are twelve bracts per whorl, located at the nodes of the cone axis. From an external view and in longitudinal section, the bracts appear to depart from the axis simultaneously. A double whorl of six bracts given off at each node is suggested, perhaps as the result of slightly oblique sections. The bracts are connate at the sessile attachment with the cone axis. The degree of fusion of the bracts is much less than in *Calamostachys binneyana*, in which the entire basal portion of the bracts is connate for a considerable distance from its insertion. The bracts are located at right angles to the axis of the cone (fig. 3; pl. 1, figs. 2 and 3; pl. 6, figs. 1 and 2). They arch around the base of the sporangia and then turn upward parallel to the cone axis. The apex of the bract slightly overlaps the base of the sporangium of the next whorl above (pl. 1, figs. 2 and 3; pl. 6, figs. 1 and 2). The vertical extent of the bracts where they parallel the axis is from 3 to 3.5 mm. The bracts vary in width depending upon the point of measurement. At the level of the base of the sporangia the bracts are about 1.25 mm. wide; at the top of the sporangia they are 500 microns. From this

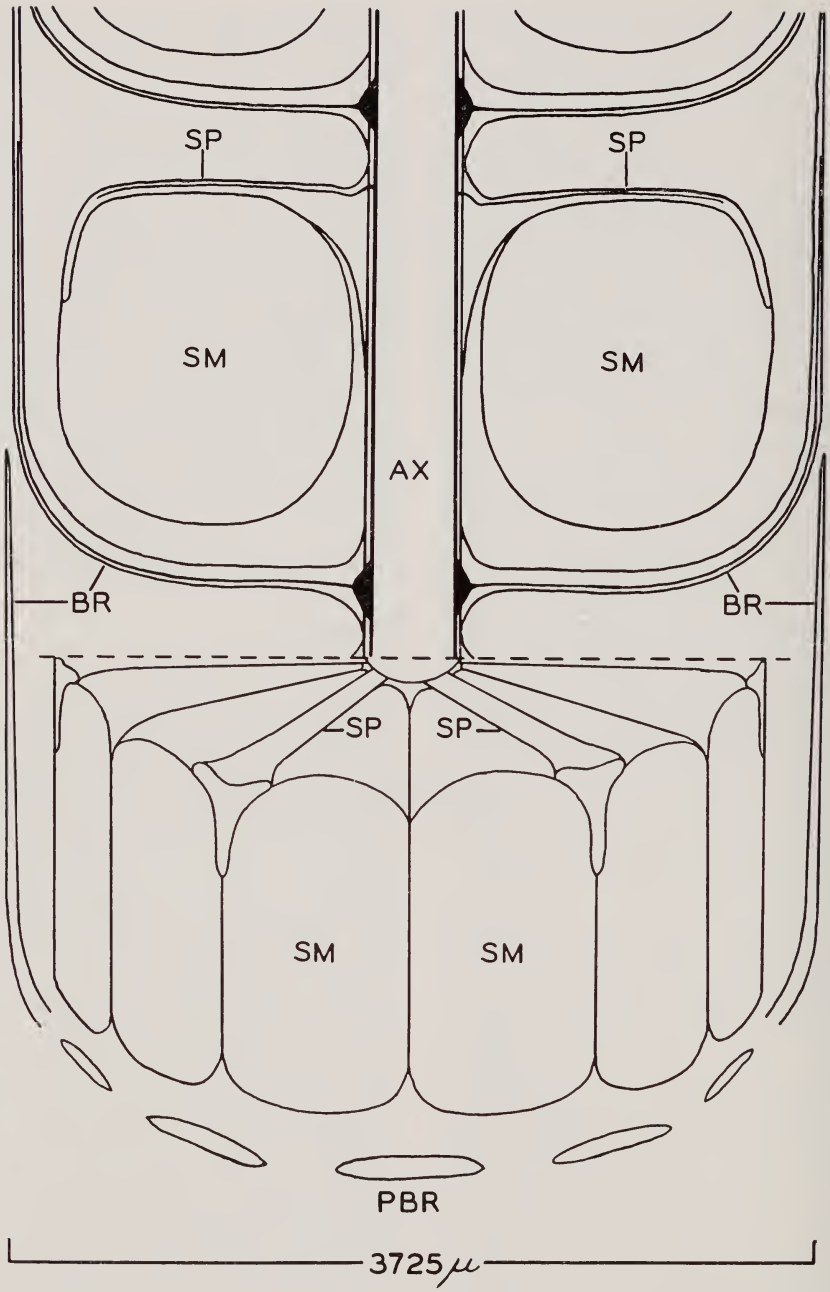

Fig. 3.—A diagrammatic reconstruction of *Mazostachys pendulata*; the lower half (below the dashed line) shows the position and attachment of the sporangiophores and sporangia. The position of the bracts is shown below. Aerenchyma tissue above the sporangia has been removed for clarity. The upper half of the drawing shows two nodes and one internode in longitudinal section. The vascular supply is shown by solid black lines. Note that the sporangia originate below the bracts of the node above and that they are pendulant. The bracts and sporangia are superposed. Abbreviations: AX, cone axis; BR, bract; PBR, position of bract; SM, sporangium; and SP, sporangiophore.

point upward their width decreases rapidly and they form a sharp apex. Where they turn upward and parallel the cone axis the bracts are about 200 microns thick; they thin to about 100 microns near the apex of the bracts. The relative position of the bracts to the sporangiophores is shown in figure 3 and in transverse section in plates 2 and 3. The twelve bracts are in both opposite and alternate positions relative to the six sporangiophores. The bracts are to the outside of, and alternate with, the twelve sporangia (fig. 4). In the early developmental stages of the cones, the bracts

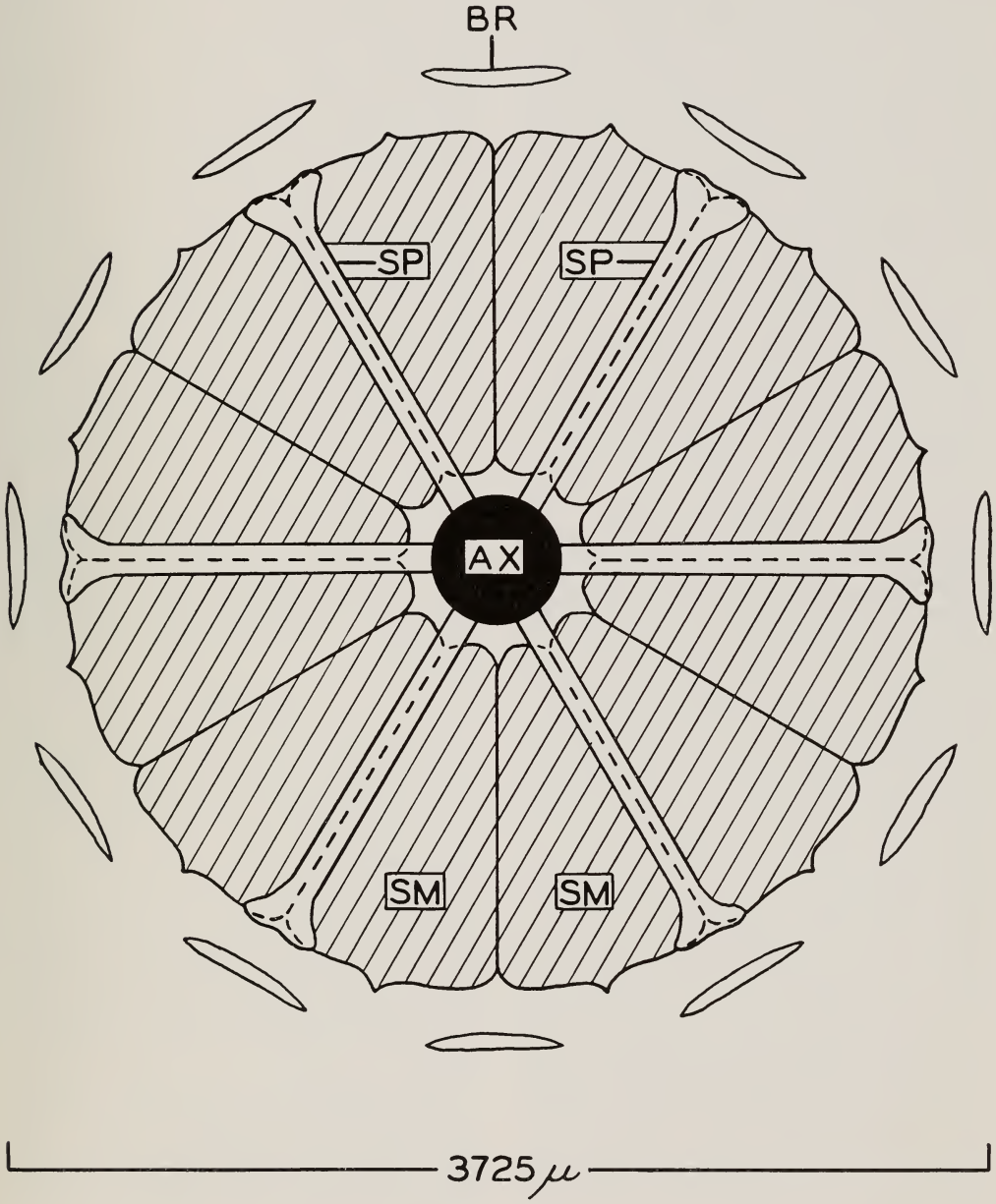

Fig. 4.—Diagrammatic transverse section of *Mazostachys pendulata* just below a node; for clarity, the aerenchyma tissue is not shown. There are 12 sporangia attached to 6 sporangiophores and 12 bracts opposite and alternate to the sporangiophore. This reconstruction is based on peels from whorl 2 of cone 14. Abbreviations: AX, cone axis; BR, bract; SM, sporangium; and SP, sporangiophore.

were closely pressed against the sporangia. Evidence for this can be seen in transverse plane, where the bracts have assumed something of the shape of the available space between the sporangia. Seen in transverse plane, the sporangia also arch at the exterior surface, which was the exposed sporangial portion between adjacent bracts.

The single vascular trace supplying each bract is median and adaxial, and it maintains this position throughout the entire bract. The tracheids of the bract trace have spiral thickenings (pl. 4, fig. 4), and the diameter of the trace is about the same or perhaps slightly smaller than that of the sporangiophore trace.

SPORANGIOPHORE

The most striking feature of *Mazostachys* is the position of the sporangiophore. It departs at right angles from the cone axis high on the internode and only slightly below the bract of the next whorl (fig. 3; pl. 1, figs. 2 and 3; pl. 6, figs. 1 and 2). The sporangiophore extends out over and between the two pendulate sporangia which it bears (fig. 3); then it curves down around the upper peripheral portion of the sporangia and parallels the axis for a short distance. Hirmer (1927) proposed the name *Metacalamostachys* for two species formerly assigned to *Calamostachys*. His reasons for creating the genus were based on the fact that the sporangiophore originated below the bract of the next whorl above and the fact that there was only one sporangium per sporangiophore. *Metacalamostachys* is known only from the compression state of preservation. This investigation is the first to report anatomical details of calamite fructifications with pendulate sporangiophores.

As stated above, the preservation of the bracts and sporangiophores leaves much to be desired, but it has been possible to locate the sporangiophore trace at its point of departure from the cone axis and also throughout the sporangiophore (fig. 3; pl. 4, fig. 5).

As the sporangiophore trace departs from the vascular bundle of the cone axis, it proceeds up and out and then bends slightly downward into the sporangiophore. There are four or five rows of tracheids with spiral thickenings (pl. 4, fig. 5) forming the trace. No gaps have been observed in the vascular bundle of the axis supplying the vascular tissue for the sporangiophores.

The departure of the sporangiophore first appears below the mid-point of the internodal region of the cone axis, but it does not become free from the axis until much higher on the internode. The mode of departure was first observed in peel 7 of cone 14, which, as nearly as can be calculated, is about 700 microns above the subtending bract. The sporangiophore continues to enlarge (pl. 2, figs. 2 and 3). Probably at one stage in their development, the sporangia were pressed against the sporangiophores; this is suggested by the contour of the underside of the sporangiophore, which parallels that of the sporangia until contact between the two is established.

The sporangiophore first appears low on the internodal region only a short distance above the subtending bract; it becomes free of the axis and receives its vascular supply at a point seven-eighths of the way up the internode.

SPORANGIA

There are twelve sporangia per whorl in mature cones, borne on six sporangiophores (two sporangia per sporangiophore). The sporangiophore forms an arm from which the sporangia hang in a pendulant manner (pl. 1, figs. 2 and 3; pl. 6, figs. 1 and 2). This mode of attachment is not peltate as in *Calamostachys* and *Palaeostachya*; instead, the sporangia hang downward as in *Cingularia* and *Metacalamostachys*. The sporangia average slightly more than 1.5 mm. in length.

The sporangial wall is usually only one cell layer thick, and this is similar to that described by Hickling (1907) for *Palaeostachya* and by Scott (1920) for *Calamostachys*. Seen in transverse plane, the individual cells are rectangular, about 100 microns long by 35 microns wide. They are

characterized by thickenings of the cell wall, which project into the lumen of the cell. These projections have been called buttresses by Hickling (1907) and stiffened projecting ridges by Scott (1920). An examination of plate 4, figure 2, reveals that a few of these may be traced the full width of the cell lumen. Such configurations are produced by thickenings that originate on the lateral wall of the cells and extend across the lumen to the opposite lateral wall. In some cells the thickenings also extend from the bottom to the top of the cell. This is probably why they do not all extend the full width of the lumen when seen in tangential view. The thickenings are somewhat similar to the partition in septate fibers; they are not true cross walls because the middle lamella does not extend into the partition. The projections of sporangial cell wells are unlike those of septate fibers in that they are thicker or at least more opaque.

As previously stated, the sporangia are only one cell thick (pl. 5, fig. 2). There is a possibility, however, that the sporangia wall gives rise to the tissue lying on top of the sporangia and extending to the sterile bracts (pl. 6, figs. 1 and 2). As seen in plate 6, figure 5, this tissue is composed of parenchyma cells between which are very large lacunae. This is similar in over-all appearance to the lacunar cortex in the free roots of *Psaronius*. A microscopic examination of the two types of tissue shows the similarity to be one of cell size plus the presence of lacunae. The cells walls of individual cells are vastly different, however; those of *Psaronius* are comparatively thin-walled, whereas those of *Mazostachys* are thicker and much more irregular. In fact, the cell-wall structure of the lacunar tissue of *Mazostachys* is similar to that of its sporangial wall and is suggestive of an epidermal proliferation of an aerenchymatous-type tissue. The extent to which the aerenchyma tissue originally covered the sporangia is unknown. Only fragmental portions of it are preserved (pl. 1, fig. 3; pl. 6, fig. 1). If the function of this aerenchymatous tissue was to protect the sporangia, it probably completely covered the sporangia. However, not a single cell of this tissue has been observed below the upper third of the sporangia. There is an organic residue at the contact between the ironstone concretion and the calcium carbonate (pls. 2 and 3), more marked in some places than others, that may represent the degradated aerenchymatous tissue.

The method of dehiscence is unknown. Hoskins and Cross (1943) found no evidence to indicate that the irregular thickenings of the sporangial wall in *Bowmanites* are similar to the thickened walls of an annulus as had been suggested by Zeiller (1893) and Williamson and Scott (1894). In *Mazostachys* the tangential walls of the sporangial cells are thinner than the radially arranged fibrous thickening. This would suggest an annulus, but unlike the sporangial wall of ferns and some bryophytes, these thickenings are present uniformly throughout all cells of the wall layer.

SPORES

Mazostachys pendulata is homosporous, and the spores from these fructifications are densely packed in the sporangia (pl. 1, figs. 2 and 3; pl. 2; pl. 3; pl. 5, fig. 2; pl. 6, fig. 1). The spores are of great value when associating the isolated calamite spores from the Illinois No. 2 coal bed with the parent fructifications, because the possibility of obtaining similar fructifications from coal balls is remote. Coal balls have been collected from the No. 2 coal bed, but they are rare and contain very poorly preserved plant remains owing to a large amount of pyrite and a low concentration of calcite. Accordingly, if affinities are to be established between isolated spores of the No. 2 coal bed and the parent fructifications, the only known source of material is from ironstone concretions with cellular structure.

The spores were examined from peels, thin sections, and in isolation. To prepare material in an isolated state, several sporangia were dissected from the rock matrix and placed in a 10 percent solution of hydrochloric acid. Within several minutes,

water was added to the samples. After six changes of water a concentrated aqueous solution of safranine Y was added. Three hours later the aqueous solution of safranine was removed by pipette. This was followed by changes of alcohol, and ultimately the spores were mounted in diaphane.

The spores are radial, trilete, round in outline, and invariably folded. Two hundred spores were measured at their largest diameter and also at right angles to the first measurement. The average diameter was 59.5 x 56.1 microns; the smallest specimen was 51.8 x 51.8 microns, the largest, 70.9 x 65.5. Most spores measured between 54.6 and 69.6 microns at their largest diameter. The trilete rays are short, usually less than 10 microns. The lips are thin but distinct, and the commissure is usually thin but also distinct. The *area contagionis* is very sharply defined (pl. 5, fig. 2; pl. 6, fig. 6). Hartung's (1933) illustrations of *Macrostachya infundibuliformis* spores show the *area contagionis* clearly but not nearly so sharply defined as in most isolated specimens from *Mazostachys pendulata.* More than 500 specimens were examined and all possessed the *area contagionis,* although it is interesting to note that this feature was less prominent in the larger specimens. By chance, several specimens had been broken and mounted in such a way that the thickness of the *area contagionis* could be measured. I had always thought that this area was greatly thickened, but surprisingly it was found to be no more than 3 microns thick, whereas the spore coat was slightly less than 2 microns. The darker color of these areas in this species is evidently not due to thickness alone, for these areas are considerably darker than those in which the spore coat may be badly folded and, therefore, thicker than the *area contagionis.* The spore coat is levigate and not more than 2 microns thick. In thin sections or peels, the spore coat appears to be slightly granular rather than levigate (pl. 5, fig. 2). In some sections it almost appeared as if there were an additional thin layer surrounding the spores.

Kosanke (1950) described the spores from the No. 2 and a number of other Illinois coal beds. Spores with calamite fructifications were assigned to *Calamospora* following Schopf, Wilson, and Bentall (1944). I found *Calamospora* to have a stratigraphic range throughout almost every coal bed examined in the Caseyville, Tradewater, Carbondale, and McLeansboro groups in Illinois and to be abundant in the last three. *Calamospora* was found in largest quantity in the lower McLeansboro group and was present in moderate abundance in the No. 2 coal bed immediately below the Francis Creek shale, the unit from which *Mazostachys pendulata* was collected. Three species of *Calamospora* were identified from the No. 2 coal bed; they are *C. hartungiana, C. flexilis,* and *C. breviradiata.* The spores of *Mazostachys pendulata* certainly are not comparable with those of the first two, and some doubt exists that they are conspecific with *C. breviradiata.* They are similar to this last species in all but one respect—the *area contagionis* is present in *C. breviradiata* but is not as clearly defined. This comparison is based not on examination of a single specimen but of many specimens, and there seems to be sufficient evidence to distinguish between them as separate species. Perhaps this distinction would not exist if the spores of *Mazostachys pendulata* were fully mature and shed from their cones. This has not been proved, however, so they must be considered distinct from *Calamospora breviradiata.*

Mazostachys pendulata was deposited less than 10 feet from the top of the coal bed, so it might be cause for concern that spores of *Mazostachys pendulata* are not known to occur in the No. 2 coal bed. The flora of the Mazon Creek ironstone concretions is well known from the works of Lesquereux (1866, 1870), Noe (1925), Darrah (1936), Schopf (1938), Janssen (1940), Stewart (1950), and many others, but this type of fructification has not previously been recorded. Also the spores, as preserved in the cones, have not been observed in any coals in Illinois. This sug-

gests that *M. pendulata* was not an abundant member of the Pennsylvanian flora of Illinois, or that the spores have undergone significant morphological changes during a late stage of development.

Diagnosis

The cones of *Mazostachys pendulata* gen. et sp. nov. are approximately 2.6 cm. long and about 4 mm. wide. They are attached by a peduncle, usually less than 2 mm. long, to a shoot with a branching pattern like that of the eucalamite group. The cone axis is a dictyostele, and the primary xylem develops centrifugally. There are six vascular bundles in the internode; they pair to form three in the region of secondary wood in the nodes. Twelve bracts arise at each node; they are in part connate at the sessile attachment with the cone axis. There are six sporangiophores, each originating just below the sterile bract of the node above. There are twelve sporangia, two attached to each sporangiophore in a pendulant manner. The sporangia are about 1.5 mm. long, and the sporangial wall is one cell thick with radial projections. A tissue composed of parenchyma with numerous lacunae covers the sporangiophores and the upper portion of the sporangia. *M. pendulata* is homosporous, the spores averaging about 60 microns in diameter, and there is a distinct *area contagionis*.

Locality.—Northern Illinois Coal Company, recreation area, secs. 29-32, T. 33 N., R. 9 E., Will County, Ill.

Horizon.—Francis Creek shale, lower portion of Carbondale group, Pennsylvanian system, Illinois.

Type specimen. — B-1304A and B-1304B, paleobotanical collection, Illinois State Geological Survey, Urbana, Ill.

Discussion

A brief review of the genera of calamite fructifications is essential to understand the similarities and differences that have an important bearing on the phyletic placement of *Mazostachys*. There are six basic types of calamite fructifications. Included in the first, or pre-*Calamostachys*, type are a number of related fructifications such as *Pothocites, Archaeocalamites radiatus, Asterocalamites scrobiculatus, Protocalamostachys,* and others. These are known only from compressions with the exception of *Protocalamostachys*, which is a petrifaction (very well described by Walton, 1949). Two other distinct types, *Calamostachys* and *Palaeostachya,* are known both from compressions and petrifactions. *Macrostachya* is of the *Calamostachys* type and is known from compressions, although some anatomical data is available as a result of Darrah's work (1936). *Huttonia* is known only from compressions; according to Hirmer (1927), it is related to *Palaeostachya.* Two more distinct types, *Cingularia* and *Metacalamostachys*, are known only from compressions. *Mazostachys*, described in this report, is the sixth type of calamite fructification.

pre-*Calamostachys* type of fructification

Calamite fructifications of this type differ from the remaining five types in that they are essentially bractless. They occur in strata assigned to the lower portion of the Lower Carboniferous, so are geologically the oldest known fructifications of the Equisetales. Their geologic age and bractless condition seem to warrant the use of this type of fructification as a starting point in developing a phyletic series.

The sporangiophores are peltate or, as Walton (1949) has indicated for *Protocalamostachys*, the sporangiophore divides into four pedicels, each bearing a single sporangium. In any case, however, each sporangiophore bears four sporangia directed toward the cone axis, as in *Calamostachys.*

Calamostachys type of fructification

This type of calamite fructification is characterized by the placement of sporangiophore whorls midway between the whorls of sterile bracts. The sporangiophores have been termed peltate, but Lacey (1943) has found that in one species, *C. binneyana*, the sporangiophore head is not

peltate but cruciate (divided into four arms). Six to sixteen sporangiophores per whorl are known, depending upon the species, and variations in number occur within some species. There are four sporangia on each sporangiophore, so the sporangia face the cone axis. The bracts of successive whorls alternate with each other, whereas the sporangiophores are superposed. Both homosporous and heterosporous species are recorded in the literature.

According to Darrah (1936), the sporangiophores in *Macrostachya thompsonii* are borne as in *Calamostachys*. This important discovery poses the problem as to whether *Macrostachya* and *Calamostachys* represent distinct genera, because the only apparent distinction is that of size.

From an anatomical standpoint, the cone axis of *C. binneyana* is best known. There is a distinct pith in this species. Surrounding the pith are three or four vascular bundles, depending upon the stele form. If there are six vascular bundles, the central axis is triangular with paired bundles; if there are eight vascular bundles, the axis is quadrangular. The vascular bundles supplying the bracts alternate in the cone axis through successive whorls. On the inside of each bundle is the carinal canal with remains of spirally thickened protoxylem. Phloem has been recognized outside the wood, so the vascular bundles are collateral. Secondary wood is found in the axis.

A comparison between *Mazostachys* and *Calamostachys* reveals certain similarities in the anatomy of the cone axis: in the central pith, in carinal canals and their arrangement in the axis, in collateral bundles, in number of sporangiophores to some extent, and in spore type. The dissimilarities are: position of attachment of sporangiophore to cone axis, number of sporangia per sporangiophore, heterospory in certain species of *Calamostachys*, and alternation of successive bract whorls of *Calamostachys*. *Calamostachys* occurs in older and younger strata than *Mazostachys*, ranging from Lower to Upper Carboniferous. The antiquity of the genus is based on the work of Bureau (1914).

Palaeostachya TYPE OF FRUCTIFICATION

This type of calamite fructification is characterized by the insertion of sporangiophores in the bract axils. The paired vascular bundles of *P. vera* depart at the nodes. According to Hickling (1907), one enters the bract and the other continues up through the axis to a point midway between the nodes, where it turns downward to the axil of the bract and out into the sporangiophore. Although the position of the sporangiophores of *Palaeostachya* is strikingly different from that in *Calamostachys*, the rest of the sporangiophore structure is similar. The number of sporangiophores per whorl in *Palaeostachya* varies with the species. There are ten sporangiophores and twenty bracts per whorl in *P. gracilis*, and sixteen to twenty sporangiophores in *P. vera* with an equal number of bracts. There are four sporangia attached to each peltate sporangiophore. The bracts of successive whorls in *Palaeostachya* are not known to alternate with one another as in *Calamostachys*. They are usually homosporous, but one species, thought to be a *Palaeostachya*, is reported to be heterosporous.

From an anatomical standpoint, the cone axis of *Palaeostachya vera*[1] is best known. It was first described by Williamson (1871), and he discussed it again later in greater detail (Williamson, 1888). He originally named the fructification *Calamites pedunculatus*, but Seward (1898) renamed it *Palaeostachya vera*. Hickling (1907) gives a very complete description.

Hickling (1907) reported that the peduncle of *P. vera* could not be distinguished from a young vegetative shoot, and that the cone axis differs only in the slight pairing of the bundles and the lack of nodal discs or sclerized cortex. The axis has a distinct pith cavity surrounded by a thin layer of parenchyma cells up to ten cells thick with sixteen to twenty carinal canals. Scott (1920) reported spiral tracheids occasionally present in the canals. The canals are

[1]Baxter recently submitted a paper on a new species of *Palaeostachya* to the American Journal of Botany, and Delevoryas is submitting a paper to the same journal describing still another species of this same genus. These two papers will greatly extend our knowledge of the genus.

paired, so the vascular bundles are in pairs and arranged alternately with the vallecular canals of the cortex. Metaxylem, secondary wood, and some phloem tissue were recognized. The cortex occupies about one-fourth of the radius of the axis and is characterized by sclerenchyma strands which Williamson (1871) called nodal discs.

Comparison of *Mazostachys and Palaeostachya* reveals a number of differences. One major distinction is the position of the sporangiophore on the internode. The sporangiophore in *Mazostachys* is high on the internode; low on the internode in *Palaeostachya.* This suggests that they possibly represent separate phyletic lines, or that one is a plant of much later origin. Smith and White's (1905) specimen from the Devonian of Maine, which they questionably assigned to *Palaeostachya,* has been examined by Dr. S. H. Mamay (personal communication), and he reports that the specimen does not show enough detail to even assign it to *Calamites.* Accordingly, the lower limit of the geologic range of *Palaeostachya* is Upper Carboniferous and the upper limit is Autunian. Thus, in geological terms, both genera first appeared about the same time.

Cingularia TYPE OF FRUCTIFICATION

Cingularia is known only from compressions, and largely through the efforts of Weiss (1876) and Kidston (1917). Two species have been described, *C. typica* Weiss and *C. cantrilli* Kidston. In the former, the strap-like sporangiophores are found inserted at the nodes immediately below the bracts. The sporangiophores bear four large pendulant sporangia which face down. The apex of the sporangiophores is divided, and two sporangia are borne on each member of this bifurcation, one behind the other. The sporangia average 5 mm. in diameter or five times that of *Calamostachys binneyana.* There are twice as many bracts as sporangiophores; they are connate for half their length and form sharply pointed teeth. Fischer (1893) found the bracts and sporangiophores adnate or partly joined to one another, a position analogous to that in the Sphenophyllales (Scott, 1920). The successive whorls of bracts are superposed, and thus do not alternate as in *Calamostachys.*

Cingularia cantrilli differs from *C. typica* in the lack of bracts; both insertions at the nodes bear four sporangia each.

Basically *C. typica* and *Mazostachys pendulata* are similar, not only as to the general position of the sporangiophores (just beneath the sterile bracts), but also with regard to the sporangia (pendulant and facing down). They differ in number of sporangia per sporangiophore, in shape and degree of bract fusion, and in the fact that the sporangiophore is inserted slightly lower on the internode in *Mazostachys.*

Both species of *Cingularia* occur in the Middle-Upper Carboniferous of Europe, which would be approximately the same stratigraphic position as *Mazostachys,* and hence both genera are of approximately the same geologic age.

Metacalamostachys TYPE OF FRUCTIFICATION

The genus *Metacalamostachys,* known only from compressions, was proposed by Hirmer (1927). *Volkmannia pseudo-sessilis* and *Calamostachys calathifera* were placed in *Metacalamostachys* by Hirmer. According to Browne (1927), *M. calathifera* is most likely a *Calamostachys.* Grand'Eury (1877) believed that *M. pseudo-sessilis* represented the cone of *Calamites palaeaceus.* Additional excellent descriptions by Jongmans (1911) and Kidston (1911) serve to clarify the morphology of this type of fructification.

The cone is attached to a shoot with foliage of *Asterophyllites palaeaceus.* Cones measure up to 2.8 cm. long and 4 mm. broad. The sporangiophores originate immediately below the bracts as illustrated by Grand'Eury (1877) or are partly fused to the bracts as illustrated by Kidston (1911). The sporangiophores are pendulant as in *Mazostachys,* and they bear one sporangium about 1 mm. long. The exact number of bracts and sporangiophores is unknown, but they are equal.

There can be little doubt that this form is closely allied with *M. pendulata* with relation to size and general organization. It differs from *M. pendulata* in that the sporangiophore is either at the node and fused with the bracts or immediately below the bract, and each sporangiophore bears a single sporangium. Also, it would appear that the sporangia are attached at a single point to the sporangiophores, in contrast to *Mazostachys,* in which the sporangia are attached to the sporangiophore arm for some distance. According to Jongmans (personal communication, 1952), there is definitely just one sporangium per sporangiophore.

Weiss' (1876) species originally described by him as *Stachannularia calathifera,* and subsequently transferred to *Calamostachys,* would appear to be a problematical form. Browne (1927) believes it to be a species of *Calamostachys,* and Hirmer (1927) has assigned it to *Metacalamostachys.* This confusion probably arose because the species is known only from compressions. The original illustration (fig. 11) by Weiss has been subject to interpretation. However, illustrations of other species of *Stachannularia* by Weiss definitely show sporangiophores with a single attached sporangium like those covered by Hirmer's genus *Metacalamostachys.*

The works of Schenk (1876) and Sterzel (1882) are interesting because the fructifications of *Annularia sphenophylloides* shown are now known to be of the *Metacalamostachys* type. This is of particular interest because of the fact that the foliage of *Annularia sphenophylloides* occurs in the same plane, although it is not organically connected, as the specimen herein described as *Mazostachys.* I have copied Schenk's (1876) reconstruction of the fructification of *Annularia sphenophylloides* (pl. 6, fig. 3). If this reconstruction is accurate, it is strikingly similar to *Mazostachys pendulata* in that the sporangiophore departs from the cone axis high on the internode just below the node and bract. However, it differs from *Mazostachys* in that the apical portion of the sporangiophore does not bifurcate and bear two sporangia but terminates, bearing one sporangium. Also, the sporangia are attached only at the end of the sporangiophore and not to the sporangiophore arm as in *Mazostachys.* The exact number of sporangiophores and bracts is unknown but they are probably equal. There are two bracts to each sporangiophore in *Mazostachys.*

A critical re-examination of all the older material would seem to be appropriate, despite the fact that perhaps little new information could be obtained because of limitations imposed by the type of preservation. It is hoped that this paper may stimulate further investigation at European institutions that have type specimens.

Metacalamostachys and *Mazostachys* are of about the same geological age; the former is from the Middle-Upper Carboniferous.

PHYLOGENY OF THE CONES OF THE CALAMITACEAE

A sound basis for a starting point in a series is the first essential in developing any phyletic relationship. The geological evidence in the case of the Calamitaceae is very helpful. As pointed out by Browne (1927), the so-called bractless fructifications, which I have called the pre-*Calamostachys* type, are geologically the oldest type known, and occur in the very lowest portion of the Lower Carboniferous. Also, some of these fructifications have been found attached to morphologically primitive calamites. They are sometimes called bractless; they may have infrequent whorls of bracts scattered over the axis at considerable intervals. Walton's (1949) *Protocalamostachys* was collected from the Calciferous sandstone on the Island of Arran. Its geologic age and anatomy place it with the pre-*Calamostachys* type of fructifications.

Browne (1927) reported the infrequent bract whorls associated with some of the bractless forms consist of almost unreduced leaves. She has postulated that the phyletically primitive forms were this type and gave rise to the bracteate types, such as

Calamostachys and *Palaeostachya*. In the bracteate types, the leaves became intercalated between the whorls of sporangiophores and functioned largely to protect the sporangia rather than as photosynthetic leaves.

The reports of Nathorst (1914), Kräusel and Weyland (1926), and others on the Middle Devonian Hyeniales have greatly clarified previous views concerning morphological interpretations of the primitive cones of the Calamitaceae. One can readily see a series from the Psilophytales to *Hyenia* and *Calamophyton* and then to the pre-*Calamostachys* type of fructification. The postulation that the bracts were originally parts of the cones and therefore primitive is immediately confronted with an obstacle—most of the pre-*Calamostachys* types were definitely bractless. Where bracts are present, they resemble leaf-like organs. Jeffrey's (1899) view that the bracts became lost in *Asterocalamites* and *Equisetum* is confronted with a problem, at least for *Asterocalamites*; *Hyenia* and *Calamophyton* may have preceded *Asterocalamites* phyletically as neither had leaves or bracts on the fertile shoots.

Walton (1949) calls attention to the nonpeltate character of the sporangiophores of *Protocalamostachys*. The sporangia are borne on short pedicels and compare with the cruciate markings in *Pothocites*. He feels that the sporangiophore may have been a forked organ comparable to the forked leaf of the Protoarticulatineae and that the peltate sporangiophore associated with the bracteate fructifications is a later modification.

Other views on the morphology and phyletic significance of bracts may be found in Bower (1908), Scott (1923), and elsewhere. An excellent review may be found in Browne (1927).

On the assumption that the bractless forms are primitive, we must decide which genus of the bracteate forms was first derived from the bractless forms. I attach considerable significance to the position of insertion of the sporangiophore on the cone axis with respect to the bracts and the number of sporangia per sporangiophore. Accordingly, the *Calamostachys* type of insertion and the number of sporangia per sporangiophore suggest that the *Calamostachys* type of fructification was derived from the *Pothocites* and *Protocalamostachys* type. Geological evidence favors *Calamostachys* rather than *Palaeostachya* if Bureau's (1914) Lower Carboniferous *Calamostachys occidentalis* is valid. Walton's (1949) statement that the peltate sporangiophore is derived by a later modification of the pedicellate sporangiophore of *Protocalamostachys* and possibly *Pothocites,* and Lacey's (1943) report that the sporangiophore of *Calamostachys binneyana* is not peltate but cruciate, may be considered evidence that certain primitive characters of the bractless genus *Protocalamostachys* are present in the well-known genus *Calamostachys*. I believe that *Calamostachys* was derived from the bractless forms during Lower Carboniferous.

I am well aware that any proposed phyletic arrangement, particularly with fragmentary fossil plants, is subject to individual evaluation of the characteristics used in developing phyletic lines. Agreement is frequently lacking, but by attempting to reconstruct phyletic development, ideas and a new perspective of the problem or problems are more clearly evident. In the case at hand, evidence can be presented suggesting a more axillary origin for the sporangiophore trace in certain species of *Calamostachys*. Hickling (1910) reports such a situation for *C. binneyana* and Browne (1927) reviews such evidence for *C. Zeilleri* and *C. magnae-crucis*. Such data certainly suggest a variance of the path of the sporangiophore trace and could be used to support the theory that *Palaeostachya* was an early derivation from *Calamostachys*, or that the first genus actually preceded. As it is clear, however, that *Protocalamostachys* preceded both *Calamostachys* and *Palaeostachya* phyletically, and that it is more closely related to the former than the latter, I believe that the axillary origin of the sporangiophore trace in certain members of the Calamitaceae was derived.

I agree with Hickling (1907) that *Palaeostachya* is derived from the *Calamostachys* type of cone but am not convinced that the sporangiophore was a ventral lobe of a sporophyll and the bract a dorsal lobe. A downward slide of the sporangiophore to an axillary position did occur, but the vascularization, at least in *Palaeostachys vera*, is not far removed from that in *Calamostachys*.

The work of Darrah (1936) has raised the question as to whether size alone is sufficient to retain *Macrostachya* distinct from *Calamostachys*. I have retained the distinction here, as shown in figure 5, but considered *Macrostachya* with the *Calamostachys* line of development. Therefore, two lines of calamite cones (fig. 5) have arisen from *Calamostachys*: the *Palaeostachya* line, terminating with *Palaeostachya* but also including *Huttonia*, and a second line, including *Mazostachya*, with *Cingularia* questionably assigned as a side branch, and terminating with *Metacalamostachys*. The *Palaeostachya* line is characterized by the axillary position of the peltate sporangiophore, four sporangia per sporangiophore, and the presence of a pith cavity. The second line is characterized by a nonpeltate sporangiophore borne high on the internode or at the next node above, and the sporangia are attached in a pendulant manner. On this main line of development there are two sporangia per sporangiophore in *Mazostachys* and only one in *Metacalamostachys*, and the pith cavity is lacking in *Mazostachys*.

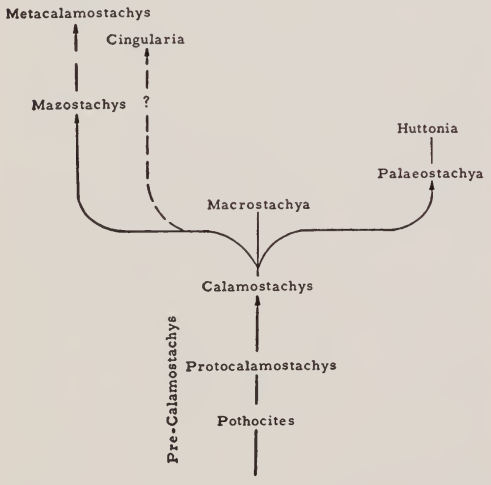

FIG. 5.—A proposed phyletic sequence for the fructifications of the Calamitaceae.

The side branch of *Cingularia* poses an interesting problem. *Cingularia* is placed in this line of development because the sporangia hang down in a pendulant manner, and the sporangiophores occur either very high on the internode or at the node above. If we exclude *Cingularia*, there appears to be a reduction in the number of sporangia per sporangiophore. There are four sporangia per sporangiophore in *Cingularia typica*, but in *C. cantrilli* there appears to be a double set of sporangiophores, each sporangiophore bearing four sporangia.

SUMMARY

1. A new type of calamite fructification from the paleobotanically famous Mazon Creek area of Will County, Ill., from the lower part of the Carbondale group of Pennsylvanian age (Francis Creek shale above northern Illinois No. 2 coal bed) is described as *Mazostachys pendulata* gen. et sp. nov.

2. *M. pendulata* is known from a combination petrification-and-compression type of preservation.

3. *M. pendulata* is characterized anatomically by a central pith and a pairing of vascular bundles with annular protoxylem, spirally thickened sporangiophore, and bract traces. Metaxylem and secondary wood have tracheids with scalariform, multiseriate scalariform, and reticulate pitting.

4. Morphologically *M. pendulata* is characterized by six sporangiophores, inserted just below the node of the next whorl above; each sporangiophore bears two pendulant sporangia. There are sterile bracts, six opposite and six alternating with the six sporangiophores.

5. Phyletically *M. pendulata* is placed above *Calamostachys* and below *Metacalamostachys*. *Cingularia* is a side branch on the main line of phyletic derivation in which *Mazostachys* and *Palaeostachya* are the basis for a forked phyletic tree.

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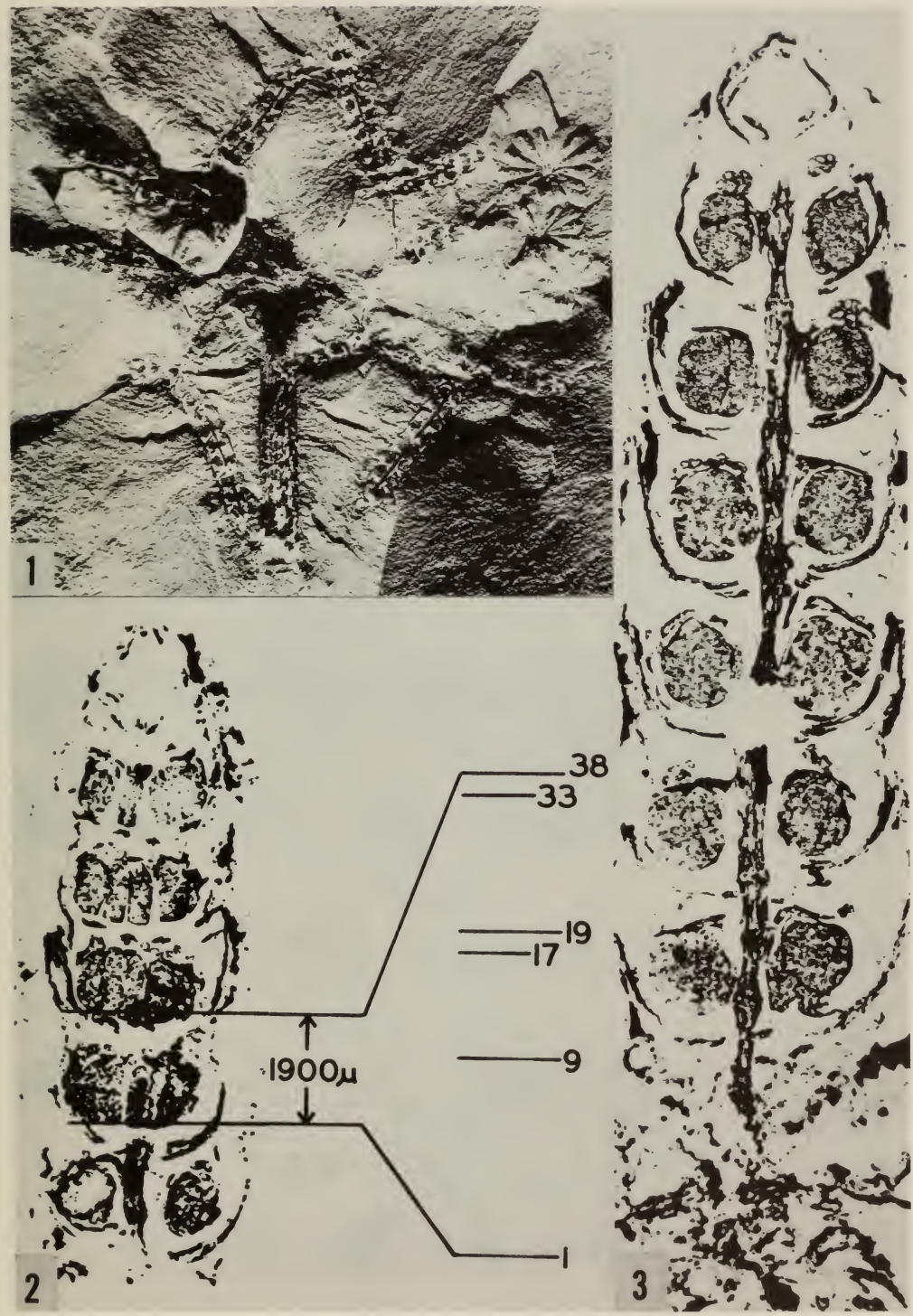
EXPLANATION OF PLATE 1

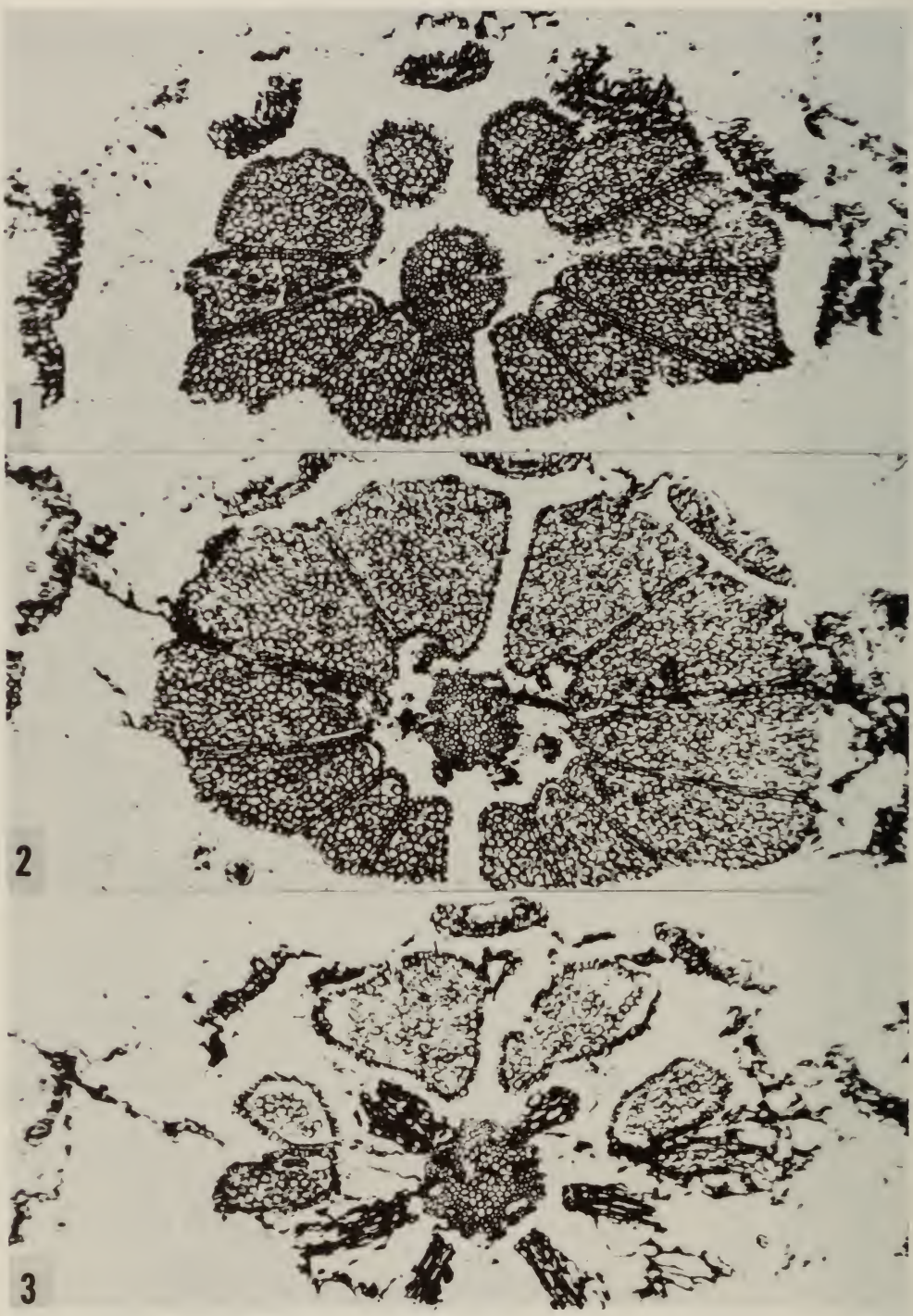
FIG. *1*—*Mazostachys pendulata* gen. et sp. nov., specimen B-1304A, shown natural size. The cones are attached by means of a short peduncle to a shoot of *Calamites* with a primary branching pattern of the Eucalamite group. The scattered foliar whorls are those of *Annularia sphenophylloides* which are not connected to *Mazostachys pendulata*.

2—A photomicrograph of B-1304A, cone 14, peel 3, of a fracture-surface peel made prior to grinding and peeling, in transverse plane. Whorl 2 of this cone covers a distance of 1900 microns. There were 38 peels taken; the peel numbers, shown in their relative position at the right, are illustrated in plates 2 and 3.

3—Essentially a longitudinal section of cone 6 from B-1304B, peel 3. This is a fracture-surface peel and shows the cone axis, nodes, bracts, sporangiophores, and apical portion of the cone (X9).



Kosanke, Mazostachys pendulata gen. et sp. nov.



KOSANKE, MAZOSTACHYS PENDULATA GEN. ET SP. NOV.

EXPLANATION OF PLATE 2

FIG. *1*—Transverse section of cone 14 (B-1304A), peel 1, from the base of whorl 2 as shown in plate 1, figure 2. The rough surface of the sporangia at the bottom represents the fracture line between the two halves of the specimen. The preserved portion of the cone axis is shown in the center surrounded by twelve sporangia and the bracts (X30).

2—Transverse section of cone 14 (B-1304A), peel 9, from whorl 2 as shown in plate 1, figure 2. The sporangiophores were first observed departing from the cone axis in peel 7. Six sporangiophore arms are seen departing from the cone axis in this peel. The position of the bracts is clearly shown at the top as is the arching of the sporangia next to the bracts. The arching is thought to be the result of the cone's compactness (X30).

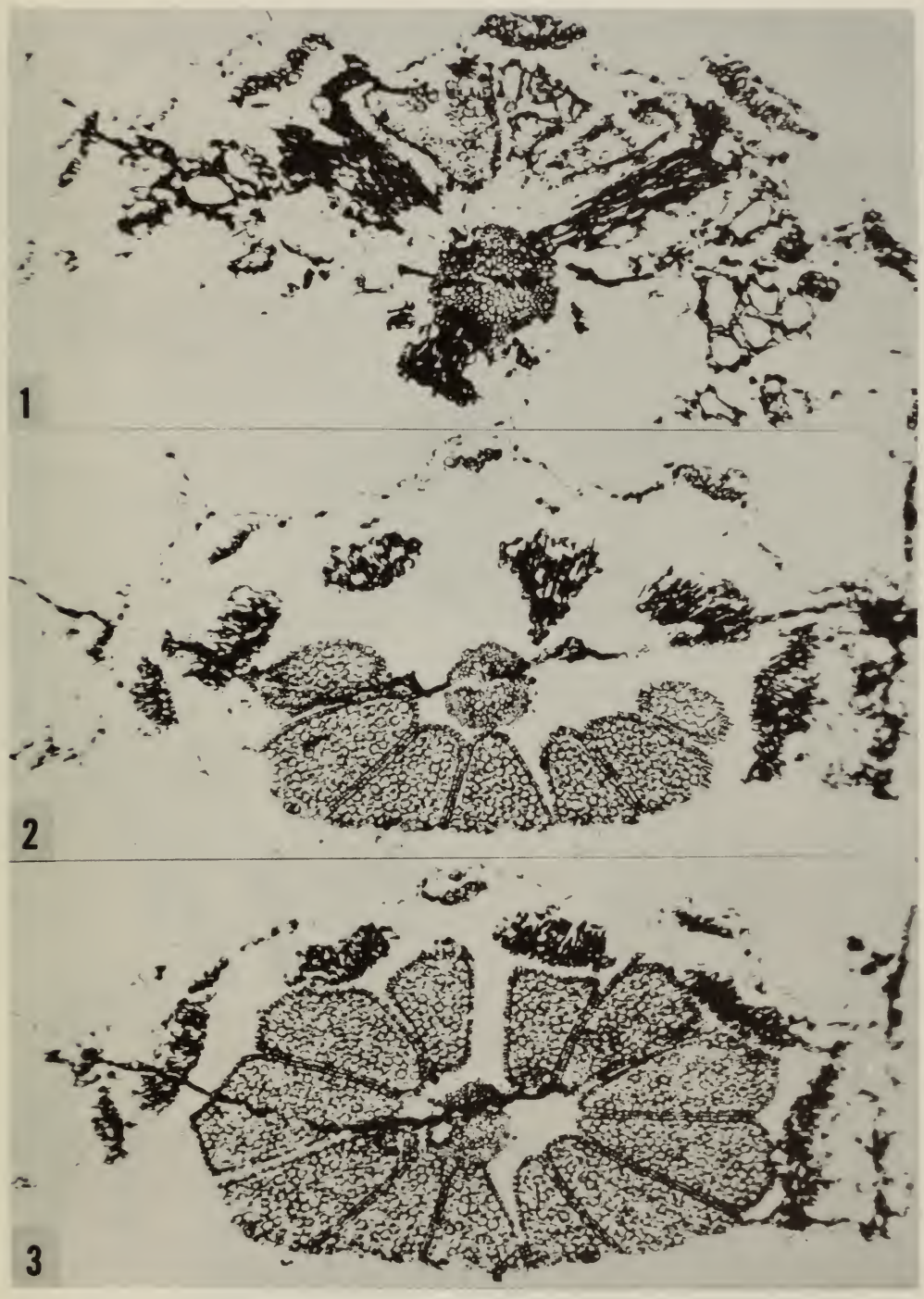
3—Transverse section of cone 14 (B-1304A), peel 17, as shown in plate 1, figure 2. All six sporangiophore arms are well developed, and the aerenchyma tissue is plainly shown to the right between the two sporangiophore arms. The absence of all twelve sporangia indicates a slightly oblique section or curvature of the cone (X30).

EXPLANATION OF PLATE 3

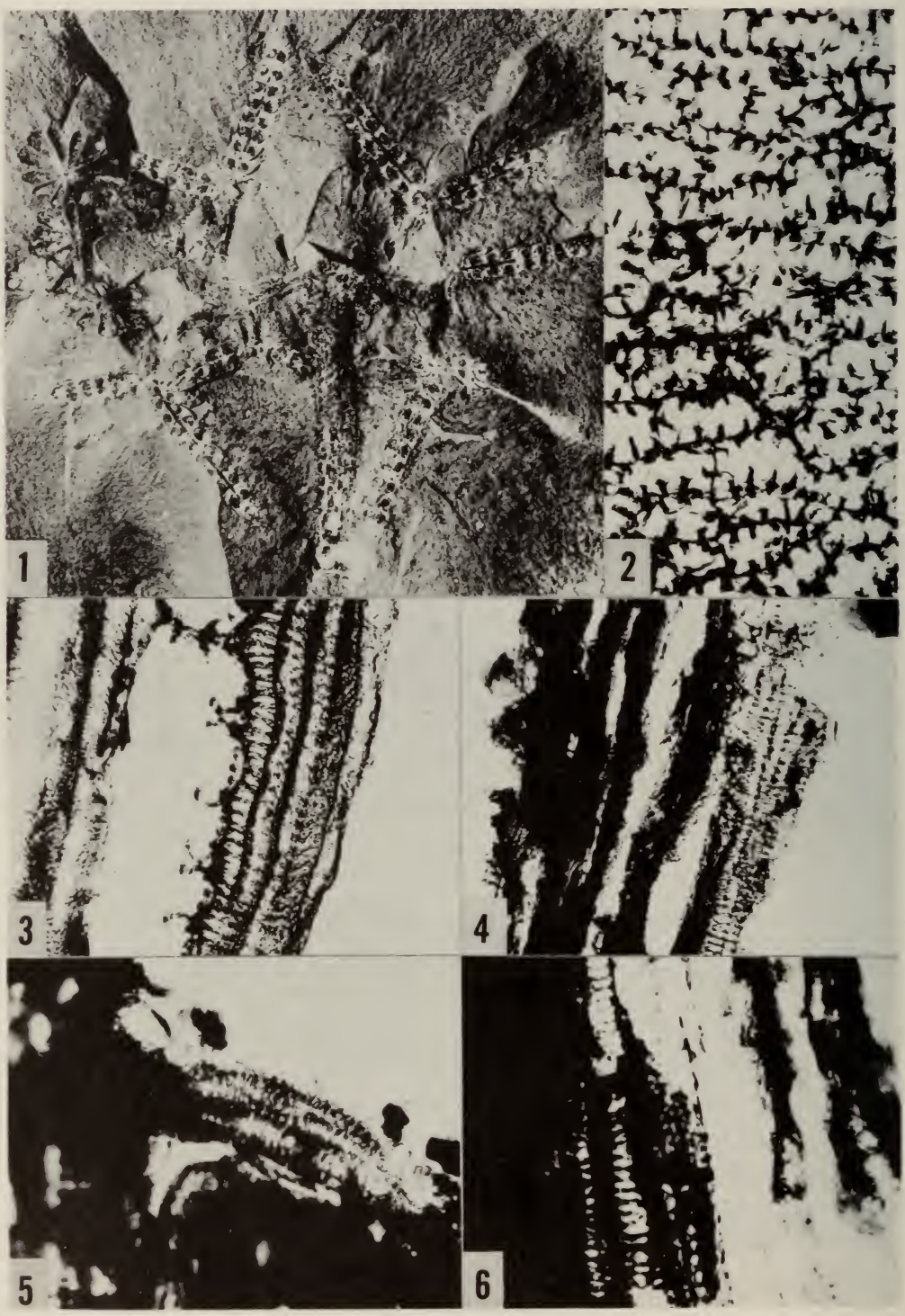
FIG. *1*—Transverse section of cone 14 (B-1304A), peel 19, as shown in plate 1, figure 2. Almost all traces of three of the sporangiophore arms have disappeared from this section, which suggests that they do not depart from the axis at precisely the same time. Further evidence of this is that the bottom arm is still present, although it should have completely disappeared first, owing to the slightly oblique section. The two sporangiophore arms in the upper half of the photomicrograph are shown in almost complete development. The arm to the left is forked at its apex and overlaps adjacent sporangia. Thus each sporangiophore arm bore two sporangia. The forking is accentuated because the arm follows the curvature of the sporangia and lies immediately above and between the two sporangia which it bore. The aerenchyma tissue with large lacunae is well shown to the right (X30).

2—Transverse section of cone 14 (B-1304A), peel 35, from the base of whorl 3 as shown in plate 1, figure 2. Seven sporangia are visible in the lower half of the section, and the bracts have begun to ascend. Note that the bracts of whorl 3 appear to be alternate with the remaining bracts from the whorl below. Actually it can be demonstrated that they do not alternate (X30).

3—Transverse section of cone 14 (B-1304A), peel 38, as shown in plate 1, figure 2. There are twelve sporangia, and this peel approximately duplicates that of peel 1 from whorl 2 one node below. The bracts appear to alternate with those from the node below, but they do not because there has been apical shifting of the bracts from whorl 2 (X30).



Kosanke, Mazostachys pendulata gen. et sp. nov.



Kosanke. Mazostachys pendulata gen. et sp. nov.

EXPLANATION OF PLATE 4

FIG. *1*—*Mazostachys pendulata* gen. et sp. nov., specimen B-1304B, shown natural size. The opposite half may be seen in plate 1, figure 1.

2—Sporangial wall tissue of a sporangium from whorl 7, cone 1, peel 3, B-1304A. The thickenings of the lateral walls are shown. Most of these do not entirely cross from one lateral wall to another, but some of them do (X175).

3—Longitudinal section from cone 13 (B-1304A), peel 4, through a portion of the cone axis showing the carinal canal with annular thickenings, all that remains of the protoxylem. Scalariform tracheids of the metaxylem are adjacent to the carinal canal (X350).

4—Longitudinal section from cone 15 (B-1304A), peel 6, through a portion of a bract showing a mass of spiral tracheids constituting the vascular trace of the bract (X350).

5—Sporangiophore vascular trace from cone 1 (B-1304A), peel 3, departing from the axis of the cone. These spiral tracheids are similar to those of the bracts (X350).

6—Longitudinal section from cone 6 (B-1304B), peel 3, through a small portion of the cone axis showing scalariform pitted tracheids (X350).

EXPLANATION OF PLATE 5

FIG. *1*—Transverse section of cone axis of cone 14 (B-1304A), peel 10. The six sporangiophore arms may be seen at the periphery of the cone axis. Six carinal canals are present, and there are remains of annular thickenings in two of the canals. Note the absence of a pith cavity (X115).

2—Two sporangia of *Mazostachys pendulata* from cone 15 (B-1304A), peel 4, showing sporangial walls and spores. The sporangia are typically completely filled with spores; the sporangial wall is one cell thick. Note the *areae contagionis* on two of the spores (X398).

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EXPLANATION OF PLATE 6

FIG. *1*—Longitudinal section of a part of whorl 4, cone 1 (B-1304A), peel 3. At the base of the photomicrograph is a portion of the sporangiophore arm of whorl 6. Above this level is the node and departing bract enclosing a sporangium. Much higher is the sporangiophore and above this the aerenchyma tissue (X43).

2—A reconstruction of two nodes and one internode showing bracts, a sporangium, sporangiophore, and above this the aerenchyma tissue. The section shown in figure 1 served as the basis for this reconstruction (X36).

3—Reconstruction of a longitudinal section of a portion of a cone associated by Schenk with *Annularia sphenophylloides*. This fructification is similar to *Mazostachys* in size and position of pendulate sporangiophores, but each sporangiophore had only one sporangium, sporangia are attached to the end of the sporangiophore, and bracts are shorter. (By Schenk from Jongmans.)

4—Oblique section through a small portion of a node from cone 13 (B-1304A), peel 6. This type of tracheid pitting was called scalariform or multiseriate pitting by Høeg (1942) and multiseriate scalariform by Delevoryas and Morgan (1952) (X357).

5—Aerenchyma tissue showing large lacunae and a network of parenchyma cells. This section is from cone 14 (B-1304A), peel 19, from the second whorl above the base of the cone (X175).

6—One spore of *Mazostachys pendulata*, obtained in the isolated state by mechanically dissecting a sporangium from a cone and macerating the sporangium in dilute HCl. The spore measures 60 microns in its largest diameter and 58.6 microns at right angles to that diameter. Note the *area contagionis* between the rays of the triradiate suture.

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